

IEA **Heat Pump** NEWSLETTER

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Ground-Source Heat Pump Systems

In this issue:

**Heat contracting for ground-source
heat pumps in Austria**

**A new ARI / ISO standard for
water- and brine-source heat pumps**

In this issue

Ground-source heat pump systems

Ground-source heat pump systems for heating-only or heating and cooling are gaining a larger market share in several countries around the world. This issue focuses on residential as well as commercial/institutional applications without underground thermal storage. Since high investment costs are still one of the main drawbacks to a further increase in the use of ground-source heat pump systems, this issue includes improved design systems and other strategies to lower costs.

TOPICAL ARTICLES

Front cover:

The photo on the front cover shows the Dutch castle Slot Loevenstein that was recently retrofitted with a heat pump (see page 12).

COLOPHON

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Hanneke van de Ven, IEA Heat Pump Centre

This article gives an international overview of the status of ground-source heat pump technology. The market status and several system types are described, with some examples highlighted.

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K. Ochifuji, M. Nakamura and Y. Hamada, Japan

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Daniel Pahud, Antoine Fromentin and Markus Hubbuch, Switzerland

This article describes the design process and the system design for a heating and cooling system in an airport building. In this case, the piles are used as heat exchangers.

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Heat contracting offers new ways to overcome the relatively high investment costs for ground-source heat pumps. In Austria this concept is increasingly used, for example in a home for the elderly in Salzburg.

Prospects for ground-source heat pumps in Europe 19

Burkhard Sanner, Germany

This article discusses the current European situation with regard to ground-source heat pumps, as well as the threats and opportunities for increased use of ground-source heat pumps in the future.

A new ARI/ISO standard for water- and brine-source heat pumps 21

Daniel Ellis, USA

An ARI/ISO standard has been developed for water- and brine-source heat pumps. This article describes the background, content and advantages of this joint standard.

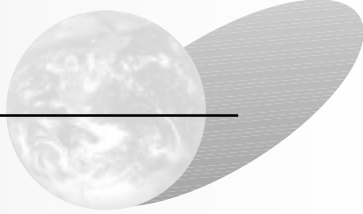
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Confidence building in ground-source applications

Modern ground-source heat pumps are well-developed, highly efficient, durable and have exceptional environmental benefits.

But for the areas of ground-source technology that are still in their adolescent stages, building confidence in geothermal applications requires that the design technology is based on sound scientific principles.



Presently, the development of techniques to identify and measure thermal properties of vertical boreholes is critical in our attempts to reduce heat exchanger investment costs.

In cooling-dominated climates, additional heat exchangers near the earth surface can be used for night-time heat rejection during summer months, when the temperature of the air is lower than that of the ground heat exchanger. Integration of this heat exchanger can reduce the long-term thermal imbalances in the ground, providing for a more efficient heat exchanger design. Short time step (1 hour or less) design models are necessary to accomplish this control. Furthermore, system design with defined energy budgets must be developed. The "Minergie" concept being developed in Switzerland is a step toward this goal.

Efforts to increase consumer confidence in geothermal technology will be strengthened by the activities of collaborative organisations such as the Geothermal Heat Pump Consortium (www.ghpc.org) and the International Ground Source Heat Pump Association (www.igshpa.okstate.edu). These organisations – consisting of manufacturers, installing contractors, government agencies, and others – exist solely to increase the quantity and quality of installations of this environmentally friendly technology. They function in a competitive market where change is suspect and past promises are not forgotten. Marketing activities in the US during 1999 will include three major conferences that will target the engineering community (Atlanta, GA, November), the research community (Stillwater, OK, May), and industry (Sacramento, CA, September).

Acceptance of geothermal technologies will come, but it will not be easy or timely unless aided by appropriate national and international collaborative partners. To preserve what has been accomplished and further increase market penetration, the technology must be appropriately applied and its applications and geographic locations carefully selected and targeted.

*James E. Bose, Ph.D., PE
Executive Director, IGSHPA
Professor and Director
Division of Engineering Technology
Oklahoma State University*

Geothermal heat pumps in Norway 25
Helge Skarphagen and Jørn Stene, Norway
Geothermal heat pumps are gaining popularity in Norway, e.g. for space conditioning of commercial buildings. This article also highlights a new design tool and opportunities for cost reductions.

NON-TOPICAL ARTICLES

Using a heat pump dryer to dehydrate agricultural products 23
Z. X. Meng, K. H. Guo, X. Huang and J. W. Zhao, China

Heat pump dryers have been introduced in China for drying agricultural products. This article describes the system used and gives an example of an application.



Heat pump news



ARI announces PrimeNet for fast directory access

USA - The Air-Conditioning and Refrigeration Institute (ARI) is offering its Applied and Unitary directories on the Internet in a new, searchable database, from the beginning of 1999. Named PrimeNet – Performance Rating Information Modified Electronically – the database at ARI's website (<http://www.ari.org>) provides product performance information that is updated continuously by manufacturers participating in ARI's certification programmes.

ARI has changed its data collection method so that manufacturers can enter their product information directly into a central database as that information becomes available. Contractors, specialists and others who for years have relied on ARI certified

information can research that same database, giving them the latest product information.

Electronic information transfer is a high priority at ARI, and PrimeNet is one of many activities that will make information available more quickly. However, all six of the ARI directories will still be offered to subscribers in the printed format for some time yet. Both Applied and Unitary directories are also available in twice-yearly updates on CD-ROM.

Source: US National Team
More information: John Nash
Tel.: +1-703-5248800
Internet: <http://www.ari.org>

Field test residential diffusion absorption heat pump

The Netherlands - A Dutch consortium of a manufacturer and utilities' organisations has initiated a field test of the residential diffusion absorption heat pump developed by the boiler manufacturer Nefit Fasto. The consortium aims to promote the sustainable use of gas. The diffusion absorption heat pump could succeed the gas-fired condensing boiler, and is also suitable for retrofit. A similar application was discussed in the IEA Heat Pump Centre Newsletter 15/1, 1997.

A total of 70 heat pumps (heating capacity 3.6 kW) will be installed in clusters of 5-10 houses. The system also includes a gas-fired condensing boiler (backup and peak load) and a thermal storage vessel. Ventilation air, outside air or ground water will be used as heat sources, depending on the location. The performance of the heat pumps will be monitored automatically for a period of one year. The diffusion absorption heat pump is expected to achieve a 20% improvement in energy efficiency compared to a gas-fired condensing boiler.

More information:
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CE labelling under the EU Pressure Equipment Directive mandatory in 2002

The Netherlands - By May 2002 CE (Committee Européen) labelling will be mandatory for any application on the European market regulated by the EU Pressure Equipment Directive (PED) (97/23/EC), which was formally adopted on 29 May 1997. This covers equipment with an internal pressure greater than 0.5 bar (50 kPa), although there are a large number of specific exclusions including items which fall under the scope of other directives (including simple pressure vessels, and machinery such as open compressors and pumps). EU countries must adopt the requirements of the Pressure Equipment Directive in their national legislation by 29 May 1999.

CEN (European Committee for Standardisation) is mandated to develop EU harmonised standards under the PED. Complying to harmonised standards is the easiest way for manufacturers to fulfil the essential requirements of the PED. CEN's Technical Committee TC 182 is working on standards for refrigerating systems and heat pumps. Their main standard EN 378 'Refrigerating systems and heat pumps. Safety and environmental requirements' is ready for formal voting by CEN member states (European Union, Switzerland, Norway, Iceland, Czech Republic). A new working group of CEN/TC 182 will be installed to update the current version of EN 378 in order to harmonise it under the PED as well as under the EU Machinery Directive.

Source: IEA Heat Pump Centre



ASHRAE 99 winter meeting Chicago

This article presents impressions from the ASHRAE 99 winter meeting in Chicago. The ASHRAE annual meeting will be held 20-23 June 1999 in Seattle.

Ground-source heat pumps

At the ASHRAE winter meeting, ground-source heat pumps received much attention, from a short course – *Design of commercial ground-source heat pumps* – for students to the technical sessions summarised below.

Thermal properties and estimation techniques of ground-coupled heat pump boreholes, grouts and fills.

Heat pump capacity, installation costs and energy efficiency depend on the thermal characteristics of the system's boreholes, grouts and fills. This is particularly relevant where installations are used for both heating and cooling, especially in cooling mode when heat is rejected to the ground. Material costs, ease of placement and availability of fills and grouts are also important. Particular aspects discussed included thermally enhanced grout behaviour, field performance testing, and thermal borehole performance modelling.

Ground water and open loop case studies

Presented case studies related to open loop, standing column and ground water systems. The use of plate heat exchangers in open loop systems was heavily debated. They are often used for safety reasons to isolate well water from the heat pump. These designs do not have to be specified for fouling factors as they are self cleaning through turbulence effects. From the cases presented it was evident that commissioning is an important factor, and that installation design should be simple.

Desuperheaters in geothermal systems

Desuperheaters can significantly improve the energy efficiency of heat pumps and air conditioners by recovering waste heat for water heating. Such systems are increasingly applied in residential and commercial installations. Methods were discussed to avoid misapplications that can degrade system efficiency.

Thermally activated systems

ASHRAE engineers are also working on thermally activated heat pumps and chillers. One symposium included six presentations (two from Germany) addressing topics such as cycle design (GAX) and simulation, and heat pump testing. Specific features discussed were a system with adjustable compositions, the use of a compact sieve in a tray distillation column, and corrosion inhibition.

TEWI

Low total equivalent warming impact (TEWI) unitary air conditioners and heat pump systems were the topic of another session. Mr Gopalnarayanan et al. (Elf Atochem) compared eight refrigerants as potential R-22 substitutes using a computer simulation. R-410A was found to have the most favourable seasonal performance factor (SPF) and TEWI among non-flammable refrigerants. Pure R-32 and a flammable blend of R-290 and R-134A have a higher SPF and a lower TEWI. Propane had a 4% higher TEWI, nearly equal to that of R-407C.

Mr Sand et al. (Oak Ridge National Laboratory) compared the TEWI of residential and commercial space conditioning equipment in North America, Europe and Japan using refrigerants R-407C, R-410A and R-290 and alternative heating/cooling technologies. It was concluded that the direct global warming potential (GWP) of the refrigerant for residential heat pumps contributes less than 7% to their total TEWI.

Standards

The Air Conditioning and Refrigeration Institute (ARI) has set out an ambitious course to adopt ISO standards as ARI standards. ARI's Water Source Heat Pump subsection was the first to adopt an international standard (ISO 13256-1): Water Source Heat Pumps. This is a unified, simplified and globally-accepted standard that will permit comparison between water-loop, ground water and ground-loop heat pumps, helping engineers and others determine system performance without requiring e.g. the separate pumping power calculations for three (previously) different standards. Starting January 2000, ARI will run a certification programme to rate and certify all water-source heat pumps under the new standard, see also p.21.

The Canadian Federal Energy Efficiency Regulations, which have set minimum levels of energy efficiency performance since 1995, have been expanded to include 15 additional air conditioners, heat pumps and other energy-using products, from 31 December 1998. The added products include dehumidifiers, ice makers and some types of central air conditioners and heat pumps. The regulations apply to

products either imported into Canada or traded interprovincially.

Utility deregulation

To date, 17 US states have passed rules for deregulation. Following this, a 10% decrease in electricity rates is mandated for all customers in California. Mr Blatt (EPRI) presented a US status impression, including pricing policies, consolidation and cultural changes.

Real-time pricing (RTP) of electricity is becoming common in the US, calculated on a per-hour basis over a 24-hour period. Customers can save money by shifting consumption to off-peak periods. An attractive way to take advantage of RTP in the US is by using alternative fuels and self generation. In the production of cooling and heating advantages can be achieved by using hybrid systems which use both electricity to power the compressor and gas to power an engine driving the compressor.

Research

ASHRAE's Technical Committees discuss which research is needed in the near future, and when appropriate, issues are selected as ASHRAE research topics. For *combustion engine-driven heating/cooling* a study entitled 'Development of emission test procedure for unitary engine-driven heat pumps' was accepted. Areas of interest include reduction of refrigerant shaft losses in compressors, noise testing methods, life cycle costs, installation guidelines and their costs.

For *unitary equipment* the results of Annex 23 (Ductless Heat Pumps) will be used to update ASHRAE's Handbook. New research is being planned in maintaining adequate space humidity levels with unitary equipment. Other topics of interest are transient heat and mass transfer in evaporators and condensers, and air-side heat transfer.

With regard to *thermally activated systems*, potential research areas include the risks of double-wall heat exchangers, guidelines for combined heat-activated and vapour compression systems and environmentally safe materials.

Enhancing environmental benefits of ground-source heat pumps (borehole sealing; thermal decay) is one of the areas of interest in *geothermal* systems. Long-term energy analysis is another topic area.

Jos Bouma, IEA Heat Pump Centre (international member of ASHRAE Technical Committees)



Optimising the brine cycle in ground-coupled heat pump systems

Switzerland - In ground-coupled heat pump systems, up to 15% of the electrical energy is often used to power the brine circulation pump. This high percentage can be reduced significantly by optimising the brine cycle and selecting the appropriate pump type. The system properties to be considered include the heat extraction load, physical properties of the brine, dimensions of pipes and boreholes, the efficiency and the minimal flow rate of the pump, the brine flow regime and the pressure losses over evaporator and manifold.

The many parameters involved make it difficult to design an energetically optimised brine cycle. A simple Excel program has therefore been developed to support this optimisation. The most

common borehole types and typical brine fluids can be chosen via pull-down menus. The pressure loss of the heat pump at nominal conditions is automatically adjusted to the effective calculated flow rate. The flow regime and its pressure drop in the borehole pipes are calculated from the system parameters, allowing an optimal brine pump to be selected. The Excel spreadsheet (in German) can soon be downloaded from the Swiss national heat pump team Internet site (<http://www.waermepumpe.ch/hpc>).

Further information is available from:
Mr A. Huber, Huber Energietechnik, Switzerland
E-mail: huber@igjzh.com
Fax: +41-1-4227953

Refinery refrigeration project receives environmental award

USA - A waste heat-powered ammonia absorption refrigeration project has been named "Environmental Project of the Year" by the Association of Energy Engineers. The project uses a new refrigeration cycle, developed by Energy Concepts Company of Annapolis, Maryland, which is powered solely by waste heat from a refinery. The system is a tri-pressure $\text{NH}_3/\text{H}_2\text{O}$ absorption cycle which incorporates highly enhanced heat and mass transfer components.

Installed at a Denver-based refinery owned by Ultramar Diamond Shamrock, the absorption refrigeration unit is used to recover 32,000 litres (200 barrels) per day of petrol and liquefied

petroleum gas which was previously flared.

The project was made possible through funding from the Office of Industrial Technologies of the US Department of Energy, and originated from Planetec Utility Services of Evergreen, Colorado. Technical assistance was provided by Argonne National Laboratory, Oak Ridge National Laboratory, and the Technology Extension Service of the University of Maryland.

Further information can be obtained from:
Ms M. Wittner, Energy Concepts Company
Fax: +1-410-2666593
E-mail: enerconcept@aol.com

New refrigerant oil saves energy and reduces maintenance

Australia - A new refrigerant oil, PERG 1000, a virtually non-hygroscopic synthetic hydro carbon, has been produced by the Pen Air Conditioning Company in Australia. According to Pen, the lubricant oil can be used with all refrigerants, thus simplifying the job of industry technicians. The product also does not harm seals, gaskets or hoses, is non-hygroscopic, non-toxic, reduces noise, prolongs machinery life and is safe for the environment. The product has been

used in refrigeration and air-conditioning systems in many different environments, including shops and supermarkets, laboratories, the dairy industry, ships, motor vehicles and office buildings.

For information:
Mr C.S. Venkat, Pen Air Conditioning Company
Fax: +61-7-33579034
E-mail: venkat@globec.com.au

Prototype CO_2 compressor presented

Germany/Italy - Compressor manufacturers Officine Mario Dorin are launching a new line in CO_2 machines. A prototype was on display at the IKK exhibition in Germany. There will be to 10 models, ranging from 1.7 to 5.4 m^3/h (equivalent to approximately 4-12 kW capacity). According to Dorin, these compressors can be particularly effective for heat pump applications.

Source: JARN, December 1998
CCI Zeitung 14/98

New US ice arena in Minnesota uses ground-coupled system

The City of Albert Lea is home to a new ice arena, one of two known arenas in the United States to use a ground-coupled system for making and maintaining the ice throughout the year.

The arena is the second in Albert Lea. The city, in collaboration with the local utility, found that a ground-coupled system would cost approximately one-third that of a conventional solution, as a result of lower installation and operating costs. Without the projected savings from energy efficiency the project would not have been built.

The ground-coupled system will not only be used for making the ice rink, but excess heat will be used for dehumidification, space heating of the arena, locker rooms and shower room, and melting shaved ice in the snow melt pit. The ice sheet itself is a 0.15 m (6 in.) slab floor with 0.46 m (18 in.) of compacted soil below it. The soil has refrigeration tubing running through it so instead of freezing only the ice sheet, the bottom soil is also frozen, enabling the ice to be frozen without using a great deal of energy.

Source: US National Team/GeoExchange
Newsletter 1/99



Final report IEA Annex 22, Compression systems with natural working fluids

The publication Final Report - Guidelines for Design and Operation of Compression Heat Pump, Air Conditioning and Refrigerating Systems with Natural Working Fluids from IEA Annex 22 (Compression systems with natural working fluids, 1995-98) will soon be available from the IEA Heat Pump Centre. The 300-page report presents Annex 22 activities and results, as well as the latest information on the design and operation of compression heat pumping systems using ammonia, hydrocarbons and carbon dioxide as working fluids.

The first two sections (The Natural Way and Annex 22 - Activities and Results) address general issues including the environmental impact of synthetic and natural working fluids in heat pumping systems, as well as Annex 22 objectives, scope, activities and results. Details are given of the 25 R&D projects that have been carried out.

The next section (Safety Aspects of Ammonia, Hydrocarbons and Carbon Dioxide) presents quantitative risk analysis, as well as risk evaluation using indices. Safety standards and regulations with regard to classification of working fluids, system design and location, occupancies and maximum working fluid charges are also described. Important physical properties and safety parameters are listed, including toxicity, flammability and high-pressure characteristics. A number of completed risk analyses are referred to.

The sections Ammonia and Hydrocarbons as Working Fluids discuss the basic properties of the fluids, focusing on design parameters, operational conditions, energy efficiency and safety aspects. Key technologies concerning the design and operation of

energy-efficient and low-charge systems are also presented. Finally, installation examples are displayed in order to demonstrate the maturity of the technologies.

Carbon Dioxide (CO₂) as a Working Fluid discusses important physical and thermophysical properties of CO₂, concentrating on the transcritical vapour compression process, dimensions of main components, energy efficiency, safety aspects and technological status. A number of promising heat pumping applications are pointed out in order to demonstrate the potential of the CO₂ technology.

The last section (Indirect Heat Pumping Systems) involves the design and application of indirect (dual-loop) heat pumping systems. A number of single-phase and phase-changing secondary fluids are presented with regard to thermophysical properties and other important parameters. Applications in commercial refrigerating systems are highlighted.

Source: Jørn Stene
Operating Agent IEA Annex 22

Australian self-service display case uses hydrocarbons

Australia - Maslen Australia is marketing a new self-service display case (for cooling prepacked meat) with 50% propane (R-290) and 50% isobutane (R-600A) as the refrigerant. The chiller is a self-contained 1,800 mm wide case with double-glazed sliding doors.

This is a DX system, with a capillary-tube expansion device. The refrigerant charge is limited to approximately 300 grams. The case is equipped with remote ballast lighting and switches outside the enclosed refrigerated space (Australian safety standard 1677-1998).

The compressor relay is located in a sealed box with special cable entries. Tubing is from copper, with all joints being brazed.

The company claims that the hydrocarbon refrigerant, apart from being environmentally friendly, offers around 20% lower compressor running costs, as well as lower compressor discharge pressure, temperature and noise.

Further information: <http://www.maslen.au.com>
E-mail: maslen@hotmail.net.au

Chiller with water as refrigerant at German university

Germany - A chiller using water as the refrigerant is being marketed by Aqua Turbo Kältetechnik. The first full-scale installation, due for completion shortly, is at the University of Essen. The 800 kW unit, part of the energy contract signed with the local energy supplier RWE, will deliver chilled water to the existing ring distribution system on the campus. Operation will be monitored by the university's department of air conditioning and applied thermodynamics, to establish actual performance. Aqua Turbo expects another 20 installations to be running by the end of 1999. Production capacity is currently around 80 units per year.

Source: JARN, December 1998

Mini ice thermal storage systems released by Japanese manufacturers

Japan - Four major Japanese air conditioner manufacturers, Daikin, Hitachi, Mitsubishi Electric (Melco) and MHI, together with electric utilities, have jointly developed small ice thermal storage systems called "Eco-Ice Mini" for light commercial applications (3.7-7.5 kW). Sales commenced in October 1998.

At night the ice thermal storage system produces ice in summer and hot water in winter. This is stored in a tank, and helps to cool and heat the building during business hours. Users benefit from lower electricity charges, because night-time power is less expensive.

This equipment could alleviate the peak demand problem in the Japanese power supply system. Both the government and nine Japanese utilities stimulate the use of this equipment by granting a subsidy and a further discount on night-time electricity.

Source: JARN 11/1998

Japanese domestic shipments down

Japan - According to the Japanese Refrigeration and Air Conditioning Industry Association (JRAIA), domestic shipments of all air conditioning equipment have dropped in the 1998 refrigeration year (RY). This is due to a deterioration in the economy and the considerable downturn in equipment investment, building construction and personal spending. Production was reduced in 1998.

Domestic shipments of room air conditioners (RACs) totalled 6.55 million units, down 8% below RY 1997. The difficult situation for this equipment is expected to continue through RY 1999. In spite of the difficult economic situation, new energy-saving room air conditioners (RACs) were launched on the market in RY 1998.

With regard to packaged air conditioners (PACs), domestic shipments totalled 682,064 units. Forty-eight percent of the Japanese PAC production was for export. An increasing number of direct expansion multi-split and VRV systems (variable refrigerant volume) are currently being adopted in small and medium-sized buildings, which is a good sign. All in all, the 1999 market is expected to be approximately equal to that of 1998.

Source: JARN, November 1998/January 1999

▼ *Table: Japanese domestic shipments of room and packaged air conditioners (RACs and PACs).*

	Oct. 1997- Sept. 1998 (RY 1998) Number of units	Change from RY 1997
RAC	6,550,958	-8.4%
Cooling only	336,588	-21.7%
Heat pump	6,214,370	-7.6%
(Inverter type)	(5,562,771)	(-3.2%)
PAC	682,064	-13.2%
Cooling only	97,198	-20.3%
Heat pump	583,886	-12%

US industry celebrates record shipments

In 1998, the air conditioning and refrigeration industry celebrated record shipments of central air conditioners and air-source heat pumps: 6,239,978 units, a 16% jump. A strong residential and commercial building market, confident consumers, low mortgage rates, continuing growth in residential remodelling and a robust replacement market combined with another warmer-than-normal year are the driving factors behind these figures. Heat pump shipments – driven by replacements and the shift in housing construction to the west and south – rose 11% to a record 1,259,695 units.

US Commerce Department data show growth of central air conditioning in all regions of the country. In the south, central air conditioning is installed in 99% of the homes while in the northeast, saturation has increased from 55% in 1993 to 67% of all new single-family homes completed in 1997.

Packaged terminal heat pumps, used in motels, hotels, nursing homes and schools, jumped around 10 percent in 1998 to achieve a seventh consecutive record. Non-residential, large unitary air conditioners and heat pumps managed to achieve a fifth consecutive record as manufacturer shipments were boosted by replacements and unusually warm temperatures.

Source: ARI's mailing service

Air conditioning will take off in the UK

UK - BSRIA and the industry foresee a boom in the market for room air conditioning in the UK over the next few years. While the air conditioning market totalled 25,000 units in 1997, BSRIA predicts 100,000 units for 2005, and 250,000 for 2015. These will be mainly portables, although packaged mini-splits could form an independent growth sector. The industry is even more optimistic. The main reasons for these predictions include increasing cooling demand, health advantages, falling prices and large promotion campaigns.

Sources: CCI, 1/99; JARN, January 1999

Price changes of HPC publications for non-member countries

From 1 May 1999 prices of most HPC products will change **for people living in non-member countries**. With the exception of the Newsletter, prices will be increased by 50%. A new pricelist will be issued in April and can be obtained from the IEA Heat Pump Centre (hpc@heatpumpcentre.org) or from our Internet site (<http://www.heatpumpcentre.org>).

In addition, postal charges will be added for non-member countries for all products. For Europe: 5% of the product price, with a minimum of NLG 10. For outside Europe: 10% of the product price, with a minimum of NLG 20.



6th IEA Heat Pump Conference Heat Pumps - A Benefit for the Environment

30 May - 2 June 1999, Berlin, Germany - The second announcement and programme for the 6th IEA Heat Pump Conference entitled "Heat Pumps - A Benefit for the Environment" are now available from the Conference Secretariat (for contact information see page 27).

The conference will highlight the benefits for the environment that come from using heat pumping technology. The environmental effects of energy use, which have long been a matter of concern, took on a new dimension with the commitments to reduce greenhouse gas emissions entered into by governments of industrialised countries in December 1997. Debate and exchange of information on these matters are essential to the realisation of these international commitments.

Source: IEA Heat Pump Centre

Annex 24 Workshop in Japan

Japan - The third Annex 24 Workshop on Absorption Systems was held in Tokyo, Japan from 28-30 October 1998. Over 30 delegates from China, Japan, Korea, Malaysia, Norway, Sweden, the Netherlands and the UK attended the workshop, which was hosted by the Heat Pump and Thermal Storage Technology Center of Japan (HPTCJ).

The workshop was organised as a two-day event plus technical visits. The pre-workshop tour was a technical visit to Sanyo Electric Co. Ltd. plant in Gunma, just outside Tokyo. The post-workshop technical tours were to Ariake sewage disposal plant and the Tokyo waterfront district heating system. A post-workshop tour to Malaysia was organised by TENAGA SPL. Sdn. Bhd. in Kuala Lumpur on 2-3 November.

The workshop programme included national presentations from the participating countries. R&D activities and applications of absorption systems in Japan, Korea, China and Malaysia were also presented. The proceedings will be available from the IEA Heat Pump Centre March 1999.

Source: Japanese National Team, December 1998

Norwegian National Team

Ms Trude Tokle from Sintef Energy Research is the new contact person for the Norwegian National Team. Address information can be found on the back cover of this Newsletter.

Source: IEA Heat Pump Centre

Annex 24 Internet site online!

The Annex 24 website is now available on the Internet at:

<http://www.ket.kth.se/Avdelningar/ts/Annex24/>

In addition to general information about the Annex, the participants and absorption technology, visitors will find useful information on case studies, R&D institutions, equipment manufacturers, reports, reference literature and links to other relevant sites. The site also features a news service, which will be updated every two months.

The Dutch Platform for Annex 24 has established its own Internet site at:

<http://www.gastec.nl/annex24>

This focuses on the Dutch sorption technology situation.

Source: Dutch National Team/
Magnus Gustafsson, Fax: +46-8-105228

Ongoing Annexes

Red text indicates Operating Agent.

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IEA Heat Pump Programme participating countries: Austria (AT), Belgium (BE), Canada (CA), Denmark (DK), France (FR), Germany (DE), Italy (IT), Japan (JP), Mexico (MX), The Netherlands (NL), Norway (NO), Spain (ES), Sweden (SE), Switzerland (CH), United Kingdom (UK), United States (US).

Ground-source heat pump systems

An international overview

Hanneke van de Ven, IEA Heat Pump Centre

Ground-source heat pump systems are slowly gaining a larger market share in some countries around the world, but many countries are still waiting for a breakthrough in the residential and commercial heating and cooling markets. The various types of systems have their own particular advantages and drawbacks, but the main general obstacle for ground-source heat pump systems has been the relatively high installation costs. This article describes several system types plus the market situation in Europe, Japan and the US.

System types

One of the most popular system types is the closed-loop ground-coupled heat pump. This consists of a reversible vapour compression cycle linked to a closed heat exchanger buried in the ground. In secondary loop systems water or brine is circulated through a liquid-to-refrigerant coil and a buried thermoplastic piping network. The distribution system can either be forced air or hydronic. In a direct expansion ground-source heat pump system, a buried copper piping network is used as one of the heat pump coils through which refrigerant is circulated.

Several heat exchanger designs are available. Vertical heat exchangers require relatively small plots of ground, use the smallest amount of pipe and pumping energy, and can result in the highest performance. However, their installation costs are higher than for horizontal systems. Wider variations in performance occur in horizontal systems, since their proximity to the earth surface leads to fluctuating ground temperatures according to weather conditions.

Ground-water heat pump systems are often also included as ground-source heat pump systems. In this case the water is pumped from a well, and after extraction of heat (or cold) the water is released in a second well or surface water. In most cases a central water-to-water heat exchanger is placed between the ground water and a closed water loop connected to water-to-air heat pumps, and to water-to-water heat

pumps. The main advantages of ground-water systems are the lower cost, the compactness of the well, the wide experience with the technology, and the fact that water well contractors are widely available. However, local environmental regulations may preclude use or injection of ground water, water may be limited, fouling precautions may be necessary if the well is not properly developed, and pumping energy may be excessive if the pump is oversized, poorly controlled or remote to the building.

Systems can be used either in warm and colder climates. In cold climates, ground-source heat pump systems are mainly used for heat extraction. When the system is used for both heating and cooling, waste energy for cooling can be used to reheat the ground. Depending on the local conditions such as the climate, condition of the ground and available alternative heating or cooling systems, the market for each type will vary widely per region and per country. The following paragraphs describe the market situation in Japan, the US and several European countries.

Japan

In Japan ground-source heat pumps are rarely used, except for some installations linked to water wells in the ground, which were extensively used for space heating and cooling of buildings until 30-40 years ago. Ground-coupled heat pumps with ground coils or borehole heat exchangers have not been given much consideration, although research and

development of such systems started in Japan at about the same time as in Europe and North America.

A few systems have been installed, primarily for experimental purposes. The reasons for the slow development of ground-source heat pump systems are the high installation costs and the fact that, apart from some extreme cold regions, the performance of air-source heat pumps is high enough to be economically justified. However, the growing concern about global warming and increasing needs for energy efficiency in buildings improves the prospect for ground-source heat pump applications in the near future.

US

In the US virtually all heat pumps are air-source types, although a growing number of ground-source heat pumps have been installed recently in residential and commercial buildings. The most popular type of ground-source heat pumps are the secondary-loop ground-coupled systems. By far the most common is the water-source heat pump (WSHP). Over 20 companies in the US and Canada manufacture water-source heat pumps. Both scroll and reciprocating type compressors are used in equipment over approximately 5.25 kW cooling capacity. Some manufacturers use rotary compressors in the smallest units (under 5.25 kW).

Annual sales of water-source heat pump units for use in ground-source heat pump systems for 1996 and 1997 are



estimated by BSRIA/Ducker (1998) at around 38,000 and 42,000 respectively. This is a relatively small share, since most heat pumps are air-source types. In 1997 heat pump sales totalled around USD 1.1 million.

In the US the ground-source heat pump consortium (GHPC), a collaboration of utilities, manufacturers and the government, has a strong promotional function. The centre's activities focus on initial cost competitiveness, confidence building and strengthening the infrastructure. This organisation aims to increase the quantity and quality of the installations with ground-source heat pumps. Their Internet site (www.ghpc.org) contains many examples of successful residential and commercial applications.

Europe

In contrast to the US, air-source heat pumps do not have such a dominating position in Europe. This is due to the fact that most of the market is based on heat demand and, as previously mentioned, the heating performance of air-source heat pumps decreases drastically at lower ambient temperatures. Ground-source heat pumps have a tradition in Sweden, Switzerland and Austria, but are now also increasing in countries such as Germany and the Netherlands. The article on page 19 discusses the European situation with regard to ground-source heat pumps in more detail. Below, markets in Switzerland, Austria and Norway are discussed, as well as a retrofit application in a Dutch castle.

Switzerland

In Switzerland, almost 40% of the heat pumps sold in 1997 were ground-source heat pumps, contributing 30% to the heat pump stock of 50,000 units. This high ratio of ground-source heat pumps results from the combined efforts of the Swiss association for the promotion of heat pumps (FWS), the Swiss heat pump manufacturers association (AWP), various research groups and

▼Table 1: Average coefficient of performance (COP) for heat pumps tested in Töss, Switzerland.

	1994	1995	1996	1997
A2/W50	2.21	2.35	2.48	2.50
A2/W35	2.77	3.14	3.27	3.43
B0/W35	3.61	3.99	4.40	4.44

A2/W50 and A2/W35 refer to an air-source heat pump with outside air temperature of 2°C and 50/35°C water supply temperature. B0/W35 refers to a ground-source heat pump with brine from a ground coil at 0°C and 35°C water supply temperature.

drilling companies with qualified staff that guarantee a high quality product.

The AWP guideline T1 'Heat Pump systems with earth heat exchangers' gives clear directions for dimensioning vertical earth heat exchangers and recommends not exceeding a heat extraction rate of 50 W/m. A large campaign of field measurements initiated by the Swiss Federal Office of Energy yielded an average seasonal performance factor (SPF) of 3.0 for ground-source heat pumps for space heating and domestic hot water. It should be mentioned that the consumption of the earth heat exchanger circulation pump and controls were included and that newly built and retrofit homes were considered.

Another important point is the correct sizing of the circulation pump. A newly developed EXCEL spreadsheet (see page 6 of this Newsletter) will make this easier in the future, by considering heat exchanger type and dimensions, specific heat extraction rate and glycol content. The resulting pressure drop and volume flow rate can then be used in commercially available pump selection programs. Correct sizing will soon yield an SPF of 4.0 for ground-source and 3.5 for air-source heat pump systems. Current average performances as determined by the heat pump test centre in Töss are shown in **Table 1**.

A study has been performed to determine the primary energy savings made by ground-source heat pumps for different electricity mixes. A monovalent brine-to-water heat pump with a vertical earth heat exchanger was compared to competing systems such as an electric resistance, oil or gas fired

heater. With the SPF's that are currently achieved, it was concluded from **Table 2** that current ground-source heat pump systems in Switzerland indeed save primary energy. This is valid in most cases, even if more unfavourable methods for the electricity production are applied.

Austria

The heat pump market in Austria is dominated by ground-coupled systems, both direct evaporation as well as secondary fluid systems, combined with low-temperature floor heating systems. The market consists mainly of new single-family houses, and the ground heat exchangers used are usually horizontally installed ground coils. The article on page 17 describes efforts to decrease the initial costs for the end-user through the mechanism of heat contracting.

Sweden

Another country where the use of ground-source heat pumps is common is Sweden. Of the 25,000 heat pumps sold in 1997, 20% used outside air as the heat source, 15% exhaust air and 65% liquid, which includes brine, ground-water and surface water. Most of the ground-source and exhaust-air heat pumps marketed in Sweden are also manufactured there. There are around 30% small and medium-sized companies specialising in heat pump manufacture and import. Although over the past 3 to 4 years total annual sales have been low, the market is now rapidly increasing due to a general upward trend in the market, combined with government activities such as information supply and a heat pump competition.



▼ *Table 2: Minimum SPF of a heat pump to save primary energy over the whole life cycle when compared to three alternative heating systems, for eight different electricity mixes. (gas: Low NO_x condensing gas boiler with an annual utilisation factor of 97%; oil: Low NO_x condensing oil boiler with an annual utilisation factor of 94%)*

Source of electricity	Electricity	Oil	Gas
CH-import: 46% hydro, 43% nuclear, 12% coal	1.0	1.9	2.0
Average European electricity mix	1.0	2.6	2.7
CHP (emissions related to heat production)	1.0	1.1	1.2
CHP (emissions related to electricity production)	1.0	3.5	3.7
Combined gas and vapour turbine cycle	1.0	1.8	1.9
Coal	1.0	3.1	3.3

Norway

Air-to-air split units used to be the most common type of heat pump system in Norwegian residential buildings, due to relatively low initial costs, easy installation and operation. However, due to the 20-30% higher SPF, almost maintenance-free design, a considerably longer lifetime and the positive impact of hydronic floor heating systems on the indoor climate, geothermal water-to-water heat pump systems are now gaining popularity. In Norway, the investment costs for a 5 kW heat pump unit including drilling, heat source connection, control system and hot water system typically range from USD 9,000 to 12,000. In addition to space heating, many units are also being used for preheating tap water.

The rock layers in central areas of Norway have many horizontal cracks that enable the ground water to circulate freely. This means that the heat extracted from the borehole will probably come from ground water rather than rock, which in turn gives a high and a relatively constant heat source temperature throughout the lifetime of the heat pump. The depth of the drilled holes typically range from 75-150 meters, depending on the heating demand, rock type and trickle of ground water in the terrain. The maximum borehole depth of 150 metres is due to the pressure limitations of the drilling equipment. Typical power and energy output from the holes are 45 W/metre and 150 kWh/metre/year. Indirect

(brine) systems are mainly being used. Due to the almost constant temperature of the brine, the systems also offer almost cost-free space conditioning during summer time if simple fan coil units are connected to the circuits.

There is also renewed interest in using geothermal heat pumps for space heating or space heating and cooling of commercial buildings, and a number of projects have recently been initiated in Oslo.

Retrofit installation

Ground-source heat pump systems can be a very efficient and economical option in new residences and commercial buildings. It is easiest and cheapest to incorporate the installation of a heat pump into the design phase of a new building. However, ground-source heat pumps can also be a suitable option for retrofit situations, as proven by a recent project in the Netherlands where a ground-water heat pump was installed in a castle (Slot Loevestijn), which dates from the 14th century. The application is outstanding since the castle is both a monument and a museum. This meant making only reversible changes to the building and reducing the visibility of the installations.

The system at Slot Loevestijn uses ground water as the heat source, which is pumped from an existing well. Two heat pumps extract heat from the water, which is then discharged into the moat around the castle. The heat produced is supplied to a central hydronic system at 40-50°C, including a floor heating system.

Around 60 million litres of ground water are used annually. The reduction in primary energy needed to heat the castle is around 50%. In future it is planned that the electricity for the heat pump is generated by windmills. Another ground-source heat pump with a brine secondary-loop system is used to heat a separate ammunition tower of the castle (the Kruittoren).

Developments

The previous overview clearly show that the market status of ground-source heat pump technology varies widely between countries, and that installation costs are generally still relatively high. On the other hand, the energy efficiency of ground-source heat pump systems is still increasing, as shown by the seasonal performance factors measured in Switzerland (Table 1). Hence, the savings that can be made compared to conventional heating systems will also continue to increase.

Efforts to reduce the initial costs concentrate on developing new design models and programs that will lead to more efficient heat pump designs, avoiding oversizing and thus avoiding extra costs. In addition, other research and development (such as the development of more efficient heat exchangers) is ongoing to increase system efficiency.

Another limiting factor is a lack of skilled installers and drilling companies, particularly experienced contractors to implement or organise all aspects of the process. In Germany developments are ongoing aimed at creating a network of companies to provide the necessary infrastructure for ground-source heat pumps. End-users would then only have to deal with one party if they wish to install a heat pump.

Hanneke van de Ven
IEA Heat Pump Centre

Reference:

Ground-source heat pumps - Design of geothermal systems for commercial and institutional buildings, S.Kavanaugh, ASHRAE, 1997.



Ground-source heat pump systems in Japan

K. Ochifuji, M. Nakamura and Y. Hamada, Japan

Although installation of ground-source heat pumps (GSHP) in Japan began in the 1980s, their use is still not widespread. The main reason for this is that the installation costs are higher than for conventional systems. There are currently only around 15 systems installed throughout the country. A few GSHPs have also been installed for melting snow on roads in snowy areas. However, around 10 universities and research institutes are currently conducting research related to underground heat exchangers and their utilisation, and their R&D potential is thought to be quite high. Thermal energy storage in the ground and its use for heat pumps have been attracting attention since the Kyoto Conference increased Japanese motivation to reduce greenhouse gas emissions. This articles describes the developments in Japan and gives some examples of applications.

History

The systems installed in the 1980s attracted attention as heat sources for heat pumps in cold climates, and were first used for cooling, heating and hot water supply in houses, hospitals, and hotels. In 1988, the Japanese government participated in Annex 15 of the IEA Implementing Agreement on advanced heat pumps systems entitled “Heat pump systems with direct expansion ground coils”. The government also stimulated the development of GSHP systems to reduce installation costs.

Despite this, installation costs are still higher than for conventional methods of energy supply (even for the direct-

expansion type), and this has hindered widespread application. In the 1990s, several new ground-source heat pump systems were installed for cooling, heating and hot water supply in welfare centres and health farms in country areas. The main reason for choosing GSHP installations is the environmentally friendly nature of these systems, with little pollution. **Table 1** shows a list of installations. All 15 systems are small-scale: the largest has 38 boreholes at a depth of 100 m.

Recently, ground-source heat pump systems have also been used as heat sources for melting snow on roads in snowy areas. However, although most road snow-melting systems use heat from the ground they do not use heat

pumps. Several hundreds of these systems have been installed, mainly in the Tohoku region.

The Japanese government also joined the IEA Implementing Agreement on “Energy conservation through energy storage”, and commissioned the Heat Pump and Thermal Storage Technology Center of Japan to promote ground-source heat pump systems in Japan within the context of Annex 8 of this agreement.

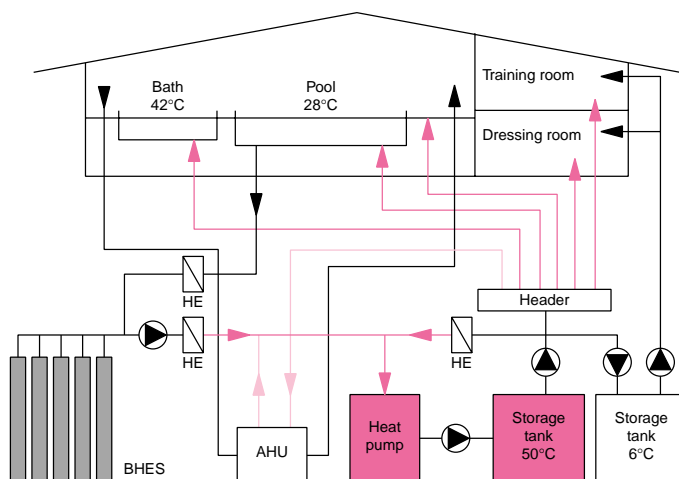
Application in a welfare centre

A welfare centre, including a swimming pool, was constructed in a rural area of Hiroshima City. The centre has a floor space of 2,010 m² and uses a 30 kW heat pump. The system is equipped with 11 boreholes to a depth of 100 m.

Figure 1 shows the layout of the system. It is used for cooling and heating the building and for heating the water in the swimming pool. The seasonal performance factor (SPF) of the heat pump is approximately 3.1. The reduction in annual fuel consumption is approximately 25,000 litres of oil equivalent compared with a conventional boiler system. Although the construction costs are approximately 1.7 times higher, the annual operating costs are USD 6,500 lower, representing a saving of approximately 30%. This results in a payback period of over 10 years.

▼ *Figure 1: Layout of a heat pump system in a welfare centre.*

Note: HE = heat exchanger, AHU = air handling unit, BHE = borehole heat exchanger.



Energy-efficient house

Another application of a ground-source heat pump system, is an energy-efficient house in Sapporo. The house is well insulated, airtight and has a floor space of approximately 192 m². **Figure 2** shows the system layout. A 1-kW heat pump is connected to two vertical underground pipes (diameter 10 cm and a depth of 30 m), and is used for floor heating and cooling. In summer, the boreholes are used for direct cooling. The heat pump COP in winter is approximately 3.2, and the primary energy reduction of the GSHP is

approximately 30%. The payback period is expected to be at least 10 years, although this period varies greatly depending on the cost of installing the underground system. As this house also uses photovoltaic power generation, it has an energy self-sufficiency rating of 90%.

Research

Despite the low penetration rate of ground-source heat pumps in the market, several universities and research institutes are conducting tests using this technology. Many tests are conducted

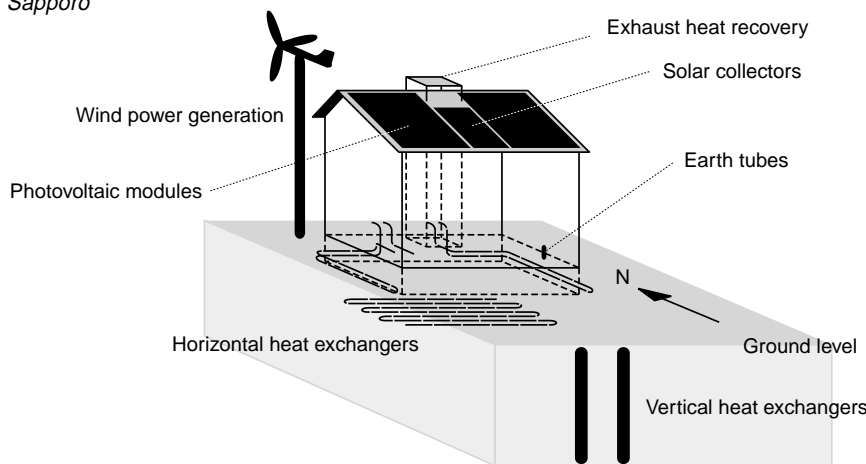
on the various types of underground heat exchangers, such as vertical, horizontal, spiral, energy pile, and direct expansion systems. Suggestions were made for GSHP applications where the basement of a building is regarded as a heat exchanger, and where horizontal pipes are buried directly under a building. Testing of GSHP systems for snow melting on roads has also been conducted on a large scale. However, most previous research projects focused on the systems' thermal properties, effectiveness in saving energy and application types, and there have been few projects looking at how to reduce installation costs to improve their economic efficiency.

▼ Table 1: Ground-source heat pump systems

Town	Year	Application	Floor area (m ²)	Heat pump capacity (kW)	Function
Sapporo	1983	House	200	2.3	H, C, HW
Sapporo	1983	House	200	5.8	H, C, HW
Sapporo	1983	Multi-family house	2,200	22.5	H, C, HW
Sapporo	1983	Hospital	2,830	63.0	H, C, HW
Tokyo	1983	Multi-family house		22.5	H, C, HW
Kyoto	1984	Hotel	4,787	112.5	H, C, HW
Hiroshima	1992	Office	1,000	3	H, C, HW
Hiroshima	1993	Health farm	1,050	45	H, C, HW
Hiroshima	1994	Welfare centre	2,010	30	H, C, Pool
Hiroshima	1996	House	120		H, C
Sapporo	1997	House	192	0.82	H, C
Houchi Pool	1998	Health farm	1,440	66	H, C, HW,
Hiroshima Pool	1998	Health farm	1,600	104	H, C, HW,
Ninohe	1995	Snow melting	266	15	Snow melting

Note: H = Heating, C = Cooling, HW = Hot water production, Pool = Swimming pool heating, SM = Snow melting.

▼ Figure 2: Renewable energy technologies used in an energy-efficient house in Sapporo



Discussion

There are several reasons for the slow market penetration of ground-source heat pumps in Japan. First, their effectiveness in saving energy and environmental conservation has not been fully recognised in the past. Secondly, original systems and technologies have not been developed in Japan. This is why installation costs for underground pipes are higher for Japan than for other countries. In addition, the fact that air-source heat pumps are popular in most areas of Japan (except for the colder areas) and are commercially successful reduces the opportunities for ground-source heat pumps. However, since the Kyoto Conference underground thermal energy storage and its use for heat pumps have received growing attention as a way of realising Japan's greenhouse gas emission reduction goals.

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Heat exchanger pile system for heating and cooling at Zürich airport

Daniel Pahud, Antoine Fromentin and Markus Hubbuch, Switzerland

The Dock Midfield, a new terminal building planned at Zürich airport, will be constructed on foundation piles that will also serve as heat exchangers with the ground. The piles will be equipped with a pipe system coupled to a heat pump for heating purposes. During the summer, part of the cooling load will be met by using the piles for direct cooling.

The Dock Midfield is a new terminal for 26 planes. The building (500 m long and 30 m wide) will be built on 350 foundation piles as the upper ground layer, consisting of lake deposits, is too soft to support the building. The piles will stand on moraine, which lies at a depth of about 30 m. With a diameter of 1-1.5 metres, the concrete piles will be cast on-site.

Renewable energies are used extensively throughout this building. Renewables are expected to meet 65% and 75% of the heating and cooling requirements respectively. The foundation piles contribute by being used as heat exchanger piles. The amount of energy purchased for heating is very small. The associated heating energy index (auxiliary energy and electricity for the heat pump), defined by the ratio of the annual energy demand and the total heated floor area, is about 30 MJ/m²y. The total electric energy index, estimated at 400 MJ/m²year, is also low for a fully air-conditioned building which will be used 18 hours a day. Construction of the Dock Midfield will start in 1999 and will continue for around four years.

Heat exchanger piles

These are foundation piles equipped with a pipe system, through which a heat carrier fluid is circulated. The two main functions of these piles are therefore to support the building and to serve as a heat exchanger with the ground. The piles are connected hydraulically and coupled to an electric heat pump. During the winter, the heat

pump extracts thermal energy from the ground and supplies heat to the building, meeting part of the heating demand. No significant regional ground water movement is expected at this site, so thermal regeneration does not take place automatically. This means that the temperature of the ground around the piles drops. This is actually an advantage during the summer when the heat exchanger piles are used for direct cooling, i.e. the flow circuit is connected directly to the cold distribution system in the building. Direct cooling enables thermal regeneration of the ground and is beneficial for heating the following winter. **Figure 1** shows a schematic view of the heat exchanger pile system.

The principal constraint on the system is that the thermal function of the piles must not cause any deterioration of their mechanical properties. In particular, the piles must not be allowed to freeze.

This temperature constraint influences the size of the heat pump which, in turn, affects the heating potential provided by the heat exchanger piles. When direct cooling is supplied, the cooling potential also depends on the temperature level of the fluid in the cooling system (maximum 20°C for this application). The annual extracted and injected thermal energy through the piles determines how the ground temperature changes over time. This can affect the thermal performance of the system. An accurate assessment of the heating and cooling potential requires a dynamic simulation of the system, including both short-term and long-term

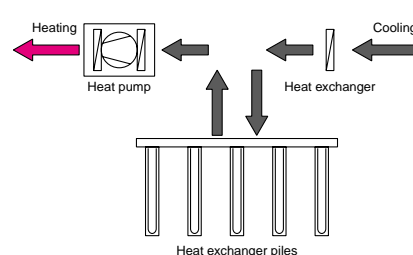
thermal performance. The system's thermal characteristics, local ground conditions and the use of an accurate simulation tool are essential elements.

Simulation tool

Simulation tools for heat exchanger pile systems have been developed by the Laboratory of Energy Systems (LASSEN), at the Swiss Federal Institute of Technology in Lausanne (EPFL). They were developed using TRNSYS, a transient simulation programme. Measurements of existing systems, were used for comparison and validation. A non-standard simulation model, devised for heat storage in the ground with borehole heat exchangers, has been adapted for heat exchanger piles. Within the framework of the Dock Midfield project, the experience gained in simulating heat exchanger pile systems was used to create PILESIM, which allows the system's thermal performance, the thermal potential of heat exchanger piles and a variety of system designs to be assessed.

The net space heating and cooling

▼ **Figure 1:** Schematic view of the heat exchanger pile system.



requirements of the building were simulated in hourly values for one year, and used as input data for PILESIM. These heating and cooling requirements take into account passive solar gains, internal gains, heat recovery units on exhaust air, free cooling with outside air and cooling for heating purposes. At this stage of the project, a constant performance coefficient of 3.5 is assumed for the heat pump.

The piles will be equipped with four U-pipes fixed on the inner side of the reinforcing steel: four plastic pipes drive the heat carrier fluid (a glycol-water mixture) down to the bottom of the pile and four others bring it back up. Even with thick piles of 1-1.5 metres in diameter, more U-pipes do not significantly improve the steady state heat transfer from the fluid to the ground in the immediate vicinity of the pile. A laminar flow regime in the piles is recommended when four U-pipes or more are used. Simulations have shown that the supplementary pumping energy needed to make the flow non-laminar is not compensated by improved thermal performance. Around 300 piles will be heat exchanger piles, each with a heat transfer length of about 25 m.

Sizing

Detailed simulations have shown that an undersized heat pump, in relation to the total length of the heat exchanger piles, does not greatly improve the performance coefficient of the heat pump. As the heat exchanger piles contribute significantly to the investment cost, an undersized heat pump results in increased cost per heat unit. On the other hand, an oversized heat pump may lead to a critical situation, as the risk of freezing exists. Freezing can be avoided by reducing the heat pump power. For the Dock Midfield, the heat pump is sized so that a power reduction of up to 10% is acceptable.

Figure 2 shows the simulated classified hourly heat and cold energy demands, together with the corresponding energy rate provided by the heat exchanger pile system. An 800 kW heat pump at the condenser will meet 90% of the 4,600 GJ (1,280 MWh) net annual heat demand. The remainder, 470 GJ (128 MWh), will be met by district heating, with a maximum peak load of 1,500 kW. Nearly all the net annual cold demand, estimated at 2,230 GJ (620 MWh), can be met through direct cooling by the pile system. However, an auxiliary cooling unit with a

cooling peak capacity of 110 kW should be available to reach the expected temperature level of the cold distribution.

A higher ground temperature means less cooling energy provided by the piles, so an increase in ground temperature over a period of time should be avoided. In order to prevent this increase, the annual extracted heat (2,950 GJ or 820 MWh) must be greater than the heat injected through cooling (2,200 GJ or 610 MWh), due to the heat dissipation from the building to the ground. Expressed per metre of pile, the annual energies and maximum thermal powers extracted and injected by the piles are relatively high, mainly due to the large pile diameter. Values are given in **Table 1**.

The economy of the heat exchanger pile system is similar to conventional heating and cooling, but has the advantage that less fossil fuels are required for heating. Direct cooling through the piles requires less electricity than a cooling machine. The electricity saved on cooling during the summer compensates for the electricity used by the heat pump during the winter.

Conclusions

Foundation piles offer an interesting alternative for providing heating and cooling energy to a building, especially when they can combine the two. Just heating or cooling requires a thermal regeneration of the ground from year to year, which can be performed naturally if the regional ground water flow is large enough. Heat exchanger piles are best integrated into a bivalent system; the peak power loads are met by auxiliary energy. The Dock Midfield presents good conditions for optimal use of heat exchanger piles. Reduced fossil fuel consumption will be realised, without increasing the overall electric energy demand.

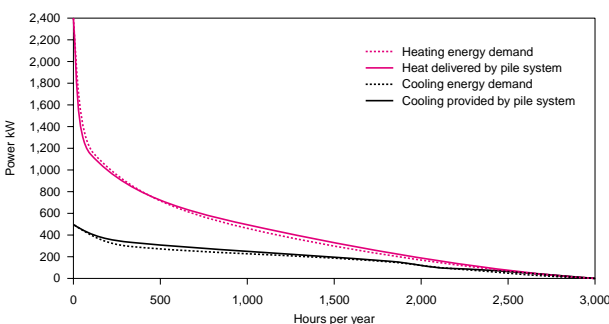
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▼ Table 1: Maximum capacity and annual energy extracted.

	Maximum capacity	Energy extracted
Heat extraction (heating)	75 W/m	110 kWh/m per year
Heat injection (direct cooling)	60 W/m	80 kWh/m per year

▼ Figure 2: Simulated classified hourly values of the net energy demands for heating and cooling the Dock Midfield. The corresponding energy rates met by the heat exchanger pile system are also shown.



Heat contracting for ground-source heat pumps in Austria

Alfred Hohla, Austria

Ground-source heat pumps enable highly efficient systems with seasonal performance factors (SPFs) of 4 or higher, providing two conditions are met. The system needs an excellent heat pump unit with a properly sized ground coil, and a well-insulated house equipped with a low-temperature heat distribution system, usually a floor heating system. For single-family houses, horizontally installed ground collectors are mainly used, while multi-family houses or other larger buildings with limited space around the building use vertical systems. Using heat contracting models to overcome the high investment costs for vertical systems offers advantages for both the contracting company and the customer.

Market status

Sales figures of heat pumps for space heating are steadily rising even though no national heat pump programme is in force. Reasons for this development can mainly be found in the activities of the Leistungsgemeinschaft Wärmepumpe (LGW) and its members, the heat pump manufacturers, distributors and installers, and in the support and promotion activities of some farsighted utilities and the incentive programmes of some provinces.

The heat pump market in Austria is dominated by ground-coupled systems, both direct evaporation as well as secondary fluid systems, combined with low-temperature floor heating systems. The market consists mainly of new single-family houses, and the ground heat exchangers used are usually horizontally installed ground coils. The installation depth is around 0.3 m below freezing depth, i.e. 1.0-1.5 m.

Installation means excavating the entire collector area then refilling it after placing the coils. However, it is also possible to excavate ditches around 0.7 m wide, install a coil then refill the ditch. Both methods ruin temporarily the garden, if one exists, though the coils can also be installed during the construction phase of the building to avoid this problem.

However, there are other applications, such as terraced houses with gardens too small for a horizontally installed collector, existing buildings with a cultivated garden, or multi-family houses or other larger buildings without enough space for a horizontally installed collector. In this case vertical ground coils have to be used, i.e. boreholes have to be drilled. The depth of the boreholes depends on the ground conditions and the drilling equipment available. Drilling is simple if uniform ground properties exist, but varying conditions, e.g. from clay to gravel mixed with rocks, cause problems and increase costs. Coils with a depth 50-100 m are currently in operation. The heat exchangers used are either coaxial, U-tube or double-U-tube. The majority of these systems are secondary loop types, but direct evaporation systems are also used. However for direct evaporation systems the maximum depth is currently limited to 50 m.

The main problem for large systems is that the heat source installation is a significant additional cost factor. Many building owners are reluctant to make such an investment. This was the starting point for SAFE, the Salzburg electric utility, to think about heat contracting models, as well as models to offer cost-effective heat-source systems.

Heat contracting

Heat contracting means supplying a building with heat, where the heat generation system is financed, constructed and managed for a fixed period by a company. As well as the operating period, the price for the heat delivered is agreed in a contract, usually linked to the price of oil. The heat price includes return on investment of the system as well as operating costs, i.e. energy and servicing. This means that customers have to pay more for the heat than if they managed the installation themselves, but they do not have the burden of investment costs, servicing and maintenance. At the end of the contract period, customers can take over the system operation or agree a new contract, which will then be cheaper because the system has been paid for. The additional costs charged by the company are then only for maintenance and servicing.

Group of buildings

The first heat contracted project carried out by SAFE was for a group of residential buildings located on the shore of a lake about 50 km east of Salzburg. Ground water heat pumps were selected for this application.

The contract for four three-storey buildings with 25 flats, equipped with floor heating systems with a maximum supply temperature of 35°C, started in



1996. The buildings are heated by two water/water heat pumps each with a heating capacity of 22 kW, with R-22 as a refrigerant. The ground water temperature in this region varies from 8-12°C during the year, and the SPF achieved in the first heating period was 3.75.

Heating of the next three buildings began in 1997. Two water-to-water heat pumps (16 kW heating capacity each) and one water-to-water heat pump (22 kW) supply heat to these buildings. The SPF of this system was 4.2; the reason for the higher SPF is the use of improved heat pump units using scroll compressors.

The contracting model used for this project was:

- the heat pump and all additional parts were supplied by the building company. The additional cost of the heat pumps and the floor heating system compared with an oil-fired heating system with radiators was paid by SAFE;
- the total additional costs for the plant were USD 100,000 (USD 54,000 were paid by SAFE);
- the initial cost for heat delivery was based on the 1995 oil price. This varied in subsequent years, 90% dependent on the oil price and 10% on the consumer price index. The cost for 1 kWh heat delivered was USD 0.06 (plus 20% taxes). Operating and maintenance costs are included, and SAFE is responsible for both;
- the contract period is 10 years.

Home for the elderly

In 1997-98 a home for the elderly was built in Salzburg. This three-storey building for 50 people contains a kitchen and various communal rooms. The heat load consists of 310 kW for space conditioning, (233 kW for space heating and 57 kW for the ventilation

system) and 30 kW for hot water production. All rooms are equipped with a floor heating system, the pitch of the tubes is 0.1-0.2 m, which guarantees a maximum supply temperature of 35°C.

Originally an oil-fired boiler was planned, but in the end a heat pump system was selected. The overall heat demand is met by three brine/water heat pumps, each with a thermal capacity of 68.3 kW. The heat pumps are equipped with scroll compressors, and the refrigerant used is the HFC mixture R-407C. For peak load operation a 50kW electric once-through heater is also installed.

The heat-source system consists of 12 vertical boreholes at a depth of 240 m. Drilling was very difficult through wet clay with inclusions of sand, i.e. it was not homogeneous.

The total cost of the system amounted to USD 207,000 for the heat pump units and USD 141,000 for the heat-source system, i.e. drilling and the heat exchangers. The additional cost compared with an oil-fired system was USD 150,000.

To cover this high additional cost SAFE, who financed and constructed the entire system, also operates this installation and delivers heat for USD 0.51/kWh, which corresponds to the current oil price. Future heat delivery costs will also be based on the price of oil. Calculations show that the payback period based on an SPF of 3.5 will be 10-15 years.

Outlook

Heat contracting offers a new market for utilities. By financing heat-source systems or total heat pump systems, the burden of the initial costs for the end-user can be removed. A new level of comfort is also created for customers; they obtain a heated home or building with no responsibility for servicing and maintenance. This strategy will also help to improve confidence in heat pump technology.

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Prospects for ground-source heat pumps in Europe

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In Europe, ground-source heat pumps have some tradition in Sweden and Switzerland, but are also increasing in other countries such as Austria, Germany and the Netherlands. This article discusses the current situation and the threats and opportunities for increased use of ground-source heat pumps in the future.

The total number of European installations using ground heat can be estimated at around 110,000 at the end of 1998 (see **Table 1**), delivering approximately 1,300 MW of heating power to residential and commercial buildings. Around 10,000-20,000 new plants per year means drilling and installing an average of 1,000-2,000 km of borehole heat exchangers or wells. Assuming that five people are needed for the drilling operation (including company overheads, around 100 m/day, 200 days/year), this secures 250-500 jobs. Work is also created in planning, heat pump manufacturing and installation, and supporting businesses.

The steady increase in the number of ground-source heat pumps can be attributed to several factors, in particular improved information dissemination and consulting activities (e.g. by utilities). Financial incentives such as special electricity tariffs or subsidies also contribute to improved market penetration. To guarantee the quality and environmentally benign behaviour of these growing numbers of ground-source heat pumps, standards and guidelines such as the German VDI-guideline 4640 "Thermal Use of the Underground" (draft published 2/1998) have been issued. Authorities are dealing with ground-source heat pumps more frequently, and this has resulted in improved knowledge. The German states of Baden-Wuerttemberg and Brandenburg, and the Swiss canton of Berne, have issued information, including maps, to help citizens and authorities conduct the licensing procedure smoothly.

Sustainability

One argument prevailing among Swiss and German scientists over the past year has been the question: how sustainable is shallow geothermal energy? Will ground temperatures continue to drop, or can the system be planned to operate at a steady ground temperature over the years, without artificial thermal recharging of the ground? Since most European ground-source heat pump plants are for heating only, the answer to this question may be crucial to increased use of the technology.

For individual plants, measurements in the Swiss village of Elgg could form the basis of an answer. (Rybach and Eugster, 1998) In 1986 a heat pump with one borehole heat exchanger (BHE) 105 m deep was equipped with monitoring devices and two holes for temperature sensors were drilled at the same depth exactly 0.5 and 1.0 m distance from the BHE, using precision directional drilling

techniques. The monitoring lasted from 1986 to 1991, and was resumed in 1996. The data was first used to calibrate a numerical simulation model, then used to simulate a 30-year operation period and temperature development over 25 years after abandoning the BHE. This highly precise investigation confirmed other extrapolations, concluding that after a period of annually decreasing ground temperature (i.e. building up a thermal gradient to the surrounding ground) a virtually steady state is achieved. When heat extraction is ceased the original ground temperature will be re-established after a few years. For the simulation, 25 years after abandoning the BHE, only variations in the order of 0.1 K will remain.

The main heat source for ground temperatures is the geothermal heat flux, i.e. the heat coming from the hot inner part of the earth. In central Europe these values are small and vary between 0.05 and 0.15 W/m². However, for large

▼ *Table 1: Estimate of ground-source heat pumps in Europe, using published information (with year) and extrapolation according to published rates of increase.*

	Number of ground-source heat pump plants	Remarks
Austria (1996)	approx. 13,000	annual increase approx. 1,600
Germany (1995)	14,000-22,000	240-450 MW thermal capacity, annual increase approx. 2,000
Netherlands (1997)	approx. 900	market development is about to begin
Sweden (1998)	approx. 55,000	approx. 330 MW thermal capacity
Switzerland (1998)	over 20,000	approx. 300 MW thermal capacity, annual increase around 10%
Total Europe (extrapolated to end of 1998)	100,000-120,000	almost 1,300 MW thermal capacity, approx. 1,950 GWh heat per year



areas the thermal power of the earth is considerable, e.g. for Germany around 25 GW. In the upper 15 m of the earth's crust, the geothermal heat flux is superimposed by the seasonal temperature variations on the surface. Any artificial decrease in ground temperature below the natural average, e.g. by borehole heat exchangers, will induce additional heat flow from all sides. The key to ground-source heat pump sizing in a heating-only scheme is not to over-exploit the ground heat and to maintain suitable temperature levels to continue the heat source for a longer period.

In conclusion, heating-only ground-source heat pumps use renewable energy from both the earth's interior and the surface, and can be operated for indefinitely long periods if sized correctly.

Housing trends

A relatively new trend in Germany and even more in the Netherlands is the use of ground-source heat pumps in residential building projects. Large numbers of houses (50 or more) are built in a limited area and equipped with ground-source heat pumps. Here the limits of the previously described phenomena may be reached for heating-only operation. Depending on the heat load of the houses and the distance between houses, the

length of the borehole heat exchanger should be increased to reach a larger ground volume.

An example is shown in **Figure 1**, based on a calculation for 60 houses. Each house has a supposed heat load of 7 kW and two borehole heat exchangers to supply the heat pump. A distance of 15 m between the heat exchangers means a total area for the house, garden, street etc. of 450 m², which is not uncommon in dense building areas. The necessary increment of borehole heat exchanger length with 15 m distance over a single, isolated plant is about 60% for a 30-year operation, and for 20 m distance (800 m²) it is still around 25%. This calculation was made without considering the influence of moving ground water. However, in a large field of houses, the impact of ground water is good for the houses upstream, and bad for those in the flow direction. For a very large area there is virtually no advantage in ground water flow.

Increased length of the borehole heat exchangers can be avoided by providing artificial thermal recovery in summertime. This may be from waste heat, warm surface water, excess heat from solar collectors, etc. If the group of 60 houses with 450 m² area each recharge 300 MWh of heat during May-September, the borehole heat exchanger length needs to be only 14% higher than for an isolated plant.

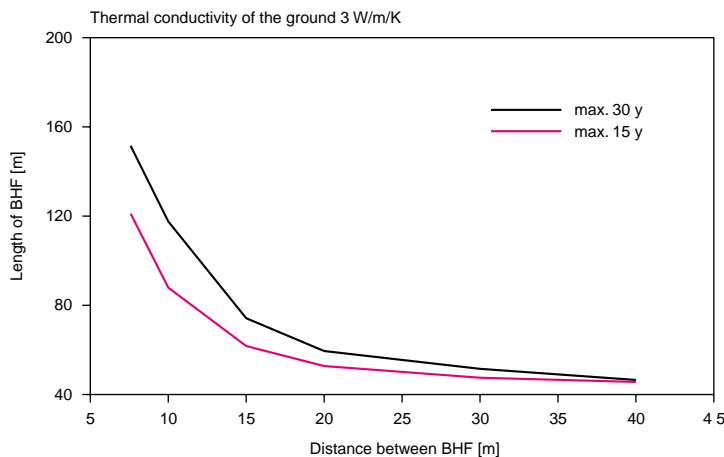
Conclusion

Ground-source heat pump technology should be adapted to new challenges, such as multiple boreholes in a small area. The system has generally proven to be sustainable, reliable and, at least in certain circumstances, economic (Sanner et al., 1998).

However, there is still a major problem with the market infrastructure in most countries, namely the lack of experienced contractors to carry out or organise all the drilling, heat pump installation, and plumbing. It would help considerably if a client only had to deal with one company for installation, maintenance and warranty. The Geothermische Vereinigung (GtV) in Germany has started to help a group of companies establish a network for providing the necessary infrastructure for ground-source heat pumps as a high-quality heating system.

In addition, there are still opportunities for optimising the technology. In Europe, there is virtually no coordination of ground-source heat pump R&D, and in most countries (with the exception of Switzerland) government support is weak. An organisation such as the US Geothermal Heat Pump Consortium is badly needed. Since the market in individual countries is too small, an initiative should be taken at European level. Meanwhile, Europeans have to look mainly to the US for new developments such as heat carrier fluids, grouting materials, etc.

▼ Figure 1: Influence of distance between borehole heat exchangers (BHE) on the necessary BHE-length for operation in a 15-year or 30-year timeframe.



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A new ARI/ISO standard for water- and brine-source heat pumps

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In accordance with long-standing policy initiatives of the Air-conditioning and Refrigeration Institute (ARI), its Water-Source Heat Pump Subsection plans to adopt an ARI/ISO standard as the basis for its certification programmes on 1 January 2000. ARI/ISO Standard 13256-1 will replace ARI Standards 320, 325 and 330. This will be the first ARI subsection to incorporate an international standard into its certification activities. This paper reviews the background, content and benefits of the new ARI/ISO standard.

The International Organisation for Standardisation (ISO) was established in 1946 to facilitate the international coordination and unification of industrial standards. There are currently 122 member nations participating in ISO's 185 technical committees, 600 subcommittees, and over 2000 working groups responsible for standards development. Recognising the growing importance of international trade, the ARI board of directors established a policy in 1989 that encouraged the active participation of its member manufacturers in ISO subcommittees and working groups. ARI's stated objectives include demonstrating leadership in the global air-conditioning market, and establishing a level playing field so that its member companies can compete more effectively.

ARI's Water-Source Heat Pump Subsection adopted ISO 13256-1 as an ARI standard in April 1998, and further directed ARI staff and the Engineering Committee to develop a plan for adopting the standard in water-source heat pump certification programmes. The subsection also directed that data should be prepared for ASHRAE (American Society of Heating, Refrigerating and Air-conditioning Engineers) and DOE (US Department of Energy) to be used in adjusting minimum efficiency requirements for water-source heat pumps under ASHRAE Standard 90.1. ARI also adopted ISO Standard 13256-2 for water-to-water and brine-to-water heat pumps in April 1998, but has currently not yet established plans for a certification programme.

Scope

The scope of ARI/ISO 13256-1 covers the following three types of heat pump systems:

- water-loop heat pumps – using temperature-controlled water circulating in a common piping loop;
- ground-water heat pumps – using water pumped from a well, lake or stream;
- ground-loop heat pumps – using brine circulating through a subsurface piping loop.

These electrically driven vapour compression systems all consist of one or more factory-made matched assemblies which normally include an indoor conditioning coil with air moving capacity, a compressor and a

Water-source subsection

The development of ISO Standard 13256-1 for water-to-air and brine-to-air heat pumps began in September 1993, under the guidance of ISO TC86/SC6/WG3, an international working group that included several members of ARI's Water-Source Heat Pump Subsection. Utilising existing ARI and CEN (European Committee for Standardisation) standards as a basis, the working group developed a draft which was first approved by the subcommittee in 1995. ISO 13256-1 was later released as a Draft International Standard in 1996 and, after circulation to all national bodies, was approved for final publication as an International Standard in April 1998.

▼ Table 1: Proposed ASHRAE 90.1 minimum efficiency changes.

Cycle	Application	Size category (kW)	Recommended minimum efficiency as of 2001 per ISO 13256-1 (COPs)
Cooling	Water-loop	<5.0	3.3
		5.0 to 19.0	3.5
		> 19.0 to <40.0	3.5
	Ground-water	<40.0	4.7
		Ground-loop	<40.0
Heating	Water-loop	<40.0	4.2
	Ground-water	<40.0	3.6
	Ground-loop	<40.0	3.1



refrigerant-to-liquid (water or brine) heat exchanger. A system may provide cooling-only, heating-only, or both functions. The three applications mentioned above were previously separately covered by ARI Standards 320, 325 and 330.

The differences in rating test temperatures for ARI/ISO 13256-1 compared to previous ARI standards are relatively minor, and consist mainly of using the Celsius scale and eliminating the dual rating points for ground-water heat pumps. Performance test temperatures vary more, but these tests are concerned only with verifying proper equipment operation under extreme conditions, and results are not published as ratings.

New concepts

The ARI/ISO standard is not design prescriptive, and allows manufacturers to specify unique air and liquid flow rates for both heating and cooling, for each step of capacity, and in each chosen application. Additionally, the ARI/ISO standard introduces the concept of “effective power input” to the heat pump, which includes the power input of the compressor and controls as well as the proportional power input of fans and pumps, whether internal or external, and whether provided by the manufacturer or not. The power input of fans and pumps is proportional in that it only includes the power required to transport air and liquid through the heat pump, and does not include arbitrary external static conditions for each application. Unlike the previous ARI standards, the power input is calculated in a consistent manner, including fan and pump power, across all applications.

Obviously, the ARI/ISO standard was developed using SI units, presenting capacities in Watts and temperatures in Celsius. One new concept was introduced: cooling energy efficiency ratio (EER) is defined in watts of capacity per watt power input. This would conventionally be called “cooling COP,” but was defined within ISO as

EER to avoid confusion with the traditional heating COP. ARI will continue to display imperial units, in addition to SI units, in its electronic and printed publications.

Benefits

Establishing an ARI-managed certification programme based on the new ARI/ISO standard will provide credibility for worldwide acceptance of ARI-rated water-source heat pump products and certification activities. This credibility would be impossible with the previous Btu/Watt-based rating standards. Perhaps more importantly, ARI/ISO certification will reduce export market entry barriers and associated costs for participating manufacturers.

The ARI/ISO standard incorporates a consistent rating methodology that includes ‘normalised’ fan and pump energy. This simplifies the use of rating data for heat pump performance modelling in seasonal energy analysis calculations, and allows for direct rating comparisons across applications. In addition, important secondary attributes of rated equipment, such as liquid pressure drop and external static capability, are incorporated into the rating determination. The new standard allows manufacturers to provide equipment optimised for ‘real world’ fluid flow rates and external static pressures, rather than for arbitrary conditions, without suffering a commensurate rating penalty. The non-prescriptive aspects of the ARI/ISO rating also accommodate advanced technology, such as variable capacity and variable fluid flow rates.

In order to evaluate the impact of the ARI/ISO standard on efficiencies, the Water-Source Heat Pump Engineering Committee conducted laboratory tests comparing ratings under the different standards for a variety of models. These results are summarised in Table 1, which is the committee’s recommended adjustments to the minimum efficiency requirements proposed for water-source heat pumps under ASHRAE 90.1 as of 2001.

Conclusion

It is highly unlikely than an international standard could be developed that did not require some change on the part of industry, regulatory agencies, or trade organisations. The adoption of ARI/ISO 13256-1 necessitates such changes. However, once fully appreciated, these changes will also bring about benefits to heat pump designers and those making equipment comparisons, both for their domestic markets and abroad. In the words of Todd W. Herrick, ARI 1998 Chairman, “We need to eliminate barriers that hinder free access to world markets. We need to recognise how international standards can help open up markets to unfettered competition.”

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Using a heat pump dryer to dehydrate agricultural products

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A new heat pump dryer has been developed in China for drying agricultural products. Characteristics of the dryer include low energy consumption, continuous moisture extraction, a programmable control system for an optimal drying process, and it is easy for individual farmers to use. This new heat pump dryer was designed especially for dehydrating agricultural products with a high economic value that need to be dried well, therefore allowing the investment to be recovered quickly. The procedures for optimisation and design of the heat pump dryer are described, as well as the economic evaluation, which indicates that a payback period of two years is expected.

Since the early 1980s, heat pump dryers have been introduced into wooded and agricultural product preservation areas in China. However, many heat pump dryers developed in China have not been efficient, so they were only economically acceptable for certain applications. Until the late 1980s, heat pump dryers in China were only used in timber industries. However, the need for proper preservation technologies for the growing agricultural production became urgent.

Conventional methods used by farmers to dry their products included direct sunshine or simple stoves. These methods usually reduce the quality and the total production. In 1997, an efficient heat pump dryer was developed by the Guangzhou Institute of Energy Conversion and tested using particularly valuable southern Chinese fruit products at on-site applications.

Simulation and design

The heat pump drying system is shown in **Figure 1**. It is a compression-type heat pump, which uses R-22 as a working fluid, although later on R-134A may be used for this application. The air from the outlet of the drying chamber is split into four paths:

- one is exhausted to the environment;
- the second flow returns directly to the inlet of the chamber to form the inner cycle of main drying air;

- the third stream is mixed with the cold air (from the evaporator) and fresh air and goes to the inlet of the condenser;
- and the last goes through the evaporator to be dehumidified by cooling the air down to its dew point.

The mixed air goes through the condenser where it is reheated before joining the main drying air. An electric heater is placed in front of the drying chamber and used for preheating if required.

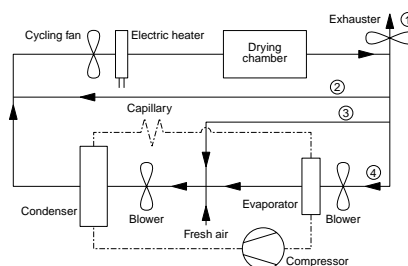
Before designing the dryer, the system was simulated to optimise the performance of the drying process. This simulation was based on the steady-state heat and mass exchanges in both the drying chamber and the heat pump. The heat and mass transfer between the drying air and the dehydrated materials is complicated since it depends on the temperature and dryness of the materials and the properties of the drying air. Using mathematical models it is difficult to predict the drying rate for a variety of individual dehydrated materials.

The heat pump drying rate, which is related to the size of the drying chamber, was determined through previous experience with crop dehydration.

The energy and mass balances in the system, which consists of the heat pump and the drying chamber, were formulated. Energy input takes place in the compressor and fan motors and through the fresh air which is sucked in. Energy output is via the condensed water which is drained off, the exhausted air, and the heat losses through the walls of the drying machine. The water extracted from the dehydrated materials equals the moisture condensed at the evaporator and exhausted with the outgoing air, while the intake air flow rate is equal to the exhausted air flow rate.

The dehumidifying heat pump is located above the drying chamber and driven by a 2 kW hermetic reciprocating compressor. The drying chamber can be fed with 500 kg of orange peel per batch.

▼ *Figure 1: Schematic diagram of the heat pump dryer.*



Continuous water extraction

During the dehydration process, the air temperature in the chamber increases and the relative humidity of the drying air decreases so that, for the same amount of air, an increasingly larger cooling capacity will be needed to cool the air down to dew point. To continue extracting water from the air and provide more dried air to dehydrate the material with a low moisture content, the air flow rate must be reduced accordingly, since the cooling capacity is limited by the power of the heat pump. A variable-speed blower is used to achieve this.

In order to dry various crops with different structures and properties, the heat pump dryer was equipped with a programmable control system installed on one of the insulated walls of the machine. Control is achieved by measuring the operation parameters at intervals (e.g. air temperature, humidity and product dryness), to achieve optimum operation resulting in high quality products and low energy consumption.

Operation and testing

The heat pump dryer was tested on two typical products: salted orange peel and longan (a southern Chinese fruit). In drying the salted orange peel, a batch of 450 kg with 77% moisture content was put in the dryer and dried with an air temperature varying between 28°C and 52°C. Throughout the drying process several “diffusion periods” were required, in which the machine was stopped to

allow time for the water to progress from the core to the surface of the peel, which is porous. The test results indicated an average water extraction rate of 8.6 kg/h and an average power consumption of 0.57 kWh per kg water (2,050 kJ/kg H₂O). The condensed moisture rate at the evaporator is about half the total water extraction rate. The drying time for the process was 34 hours and the energy consumption was much less than for conventional drying methods. The dried peel had a good colour and an even dryness, and a Chinese food company judged the quality to be better than those dried by their current techniques.

Economic aspects

The economy of the heat pump dryer was studied by drying a sample of longan. Investment costs included a machine payment of USD 6,090. A sensitivity analysis shows that the payback period is highly dependant on the prices of the fresh and dehydrated products (see **Figure 2**). In Guangzhou, the price of fresh longan was around USD 1.3/kg (on average) and the dried longan cost USD 4.87-7.31/kg, depending on the quality of the product. As the product quality will be high as a result of the advanced heat pump drying process, the price of the dried longan products will be at least USD 6.0/kg, which results in a payback period of two years.

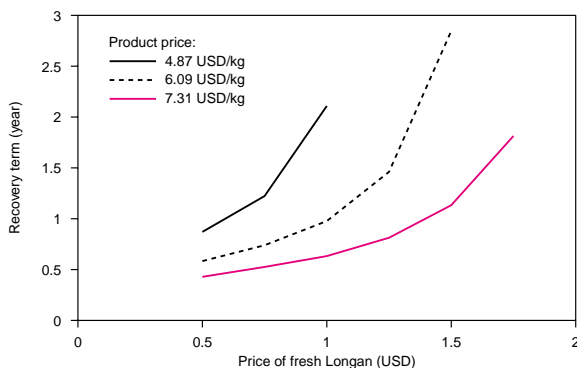
Remarks

Several remarks can be made as a result of the study. Under optimum circumstances the heat pump dryer has a low average electrical consumption of 0.57 kWh/kg H₂O for a dehydrated product of moderate difficulty, such as orange peel. The energy saving, high product quality and independence from weather conditions will benefit the dehydrating of agricultural products.

It is also economically advantageous for individual farmers to have a programmable controlled heat pump dryer. The production, quality and power consumption depend on the characteristics of the dehydration processes. On-site experiments may be necessary to obtain the best heat pump drying operation.

Finally, because of the warm climate in southern China, adding an exterior condenser to the heat pump dryer will be helpful. In this case the mixed airstream after the evaporator is not reheated by the heat from the condenser. This heat is dissipated outside the system. This can reduce the air temperature in the drying chamber to below 10°C and avoid ruining heat-sensitive materials during the early stages of the drying process, where low temperatures and humidity are required. Nowadays, about 50 heat pump dryers have been installed in Guangdong, Shandong, Zhejiang and some other provinces of China for drying agricultural products such as fishes and seeds. In Guangdong, the yearly production of fruits and fish is about 10 million tonne in 1997 and increases by 10% each year. If 10% needs to be dehydrated and half of these products are dried by heat pump dryers, the total heat pump capacity will be about 40 MW. In that case over 22,000 of these heat pump dryers will be needed. The potential market in China for this type of heat pump dryers is predicted to be more than 100 MW.

▼ Figure 2: Sensitivity analysis of the payback period.



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Geothermal heat pumps in Norway

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Since electricity generation in Norway is almost entirely based on hydropower, electrically driven heat pumps represent an environmentally clean and energy-efficient technology which can be used in buildings and industrial processes. In recent years the most common heat pump system in Norwegian residences has been air-to-air split units, due to their relatively low initial costs, easy installation and operation. However, geothermal heat pump systems are now gaining popularity in Norway, because of the 20-30% higher seasonal performance factor (SPF), the lack of maintenance required, the longer lifetime, and considerably higher heating capacity at low ambient temperatures. There is also a renewed interest in using geothermal heat pumps for space conditioning of commercial buildings, and a number of these projects have recently been initiated.

Norwegian bedrock

Low electricity prices have been the main reason for the extensive use of direct electric heating in residences and commercial buildings in Norway. However, owing to the current shortage of hydroelectric power in the Norwegian energy system and the subsequent import of electricity based on fossil fuels and nuclear power from central Europe, the importance of energy conservation and a transition to more sustainable heating systems are now being stressed by the Norwegian Government. Geothermal heat pumps represent one important option.

The geological conditions in Norway and Sweden are rather similar, and Norwegian heat pump suppliers and drilling companies have therefore been able to benefit from the outstanding Swedish experience and methods. All the Norwegian bedrock consists of crystalline hard rock, and the ground water flow follows fissures. The rock itself is impermeable. Most of the Norwegian landscape consists of hills and slopes, and the relatively high ground water flow improves the quality of the boreholes when they are used as heat sources for heat pump systems. Measurements in selected wells have demonstrated that the heating capacities may be twice as high as that of “dry” wells where the heat flux is mainly determined by the thermal properties of the bedrock.

New design tool

The Geological Survey of Norway (NGU) and the Norwegian Water Resources and Energy Directorate (NVE) are currently developing an Internet-based design tool for sizing energy wells. The project is financed by the Norwegian Research Council. Initially, the bedrock measurements of thermal conductivity will be limited to a number of selected densely populated

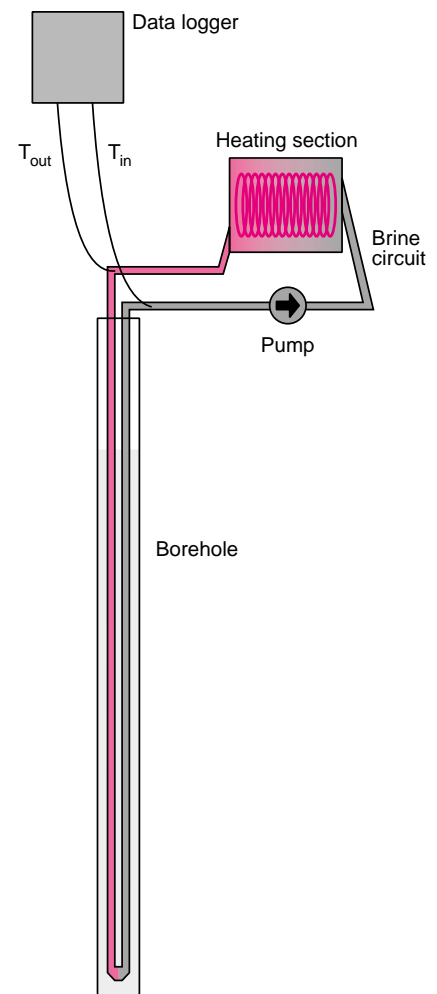
▼ *Figure 1: Equipment used for the thermal response test.*

Principle of measurement

Heat is added to the brine in the closed circuit, and the inlet and outlet temperatures of the brine are measured. The thermal response of the borehole or energy well is determined by the measured temperature difference, i.e.

$T_{out} - T_{in}$. The measuring normally takes 50 hours, since a stable situation is required. The measuring results mainly depend on the:

- depth of the borehole;
- thermal conductivity of the rock;
- specific heat capacity of the rock;
- groundwater flow;
- groundwater level;
- thermal properties of the heat exchanger tube.



areas close to the capital, Oslo. The database is made by linking digital proprietary data (addresses) to the bedrock maps, together with the measured thermal conductivity of the different types of rock.

Using a thermal response test rig developed by the Division of Water Resources and Engineering, Luleå University of Technology, Sweden (**Figure 1**), it is possible to measure the properties of the entire energy well, including both the impact of the thermal properties of the bedrock and the ground water flow. Unfortunately, a complete test takes about 50 hours, which may limit the use of the equipment.

In the future NGU and NVE want to combine the results from the thermal response tests with the thermal conductivity data of the bedrock, the results from a ground water well database, and topographical data of the catchment area. By combining this information they can improve the basis for the design of energy wells for geothermal heat pump systems.

Cost reductions

In order to make geothermal heat pumps a more cost-efficient alternative to direct electric heating, oil-fired systems and bioenergy, it is important to reduce the drilling costs of the energy well. Using high-pressure drilling equipment (25 kg/cm²), Scandinavian drillers are capable of drilling 15,000 to 20,000 metres per year per drilling rig, assuming a borehole diameter of 150 mm. This is higher than that of drillers in central Europe. Despite the use of high-pressure equipment, very few accidents have been reported.

The Scandinavian market leader in drilling rigs is NEMEK, located in Telemark, Norway. They have developed special rigs for drilling energy wells, with wide rubber caterpillar belts that minimise damage to the surface. This relatively compact rig, made for narrow back yards, typically costs USD 135,000. Then there are the costs of the compressor, truck and drilling tools. A complete drilling rig manufactured in Norway therefore costs around USD 400,000. In the Oslo area,

where most of the geothermal heat pumps have been installed, a complete energy well, including a 40 mm brine circuit, costs around USD 25 per metre (VAT included). The well represents about 30% of the total costs of a 5 kW residential heat pump installation. In the future, increased competition, better dimensioning, and the use of high-pressure water-driven drilling equipment are expected to reduce the costs of energy wells.

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CD-ROM Energie - Volume 4: Wärmepumpen

Available from: Fachinformationszentrum Karlsruhe, MSV, Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen, Germany. Fax: +49-7247-808135. Price: DM 95 (excluding postage and VAT).

The CD-ROM contains literature references, and several search possibilities to obtain an overview of state-of-the-art heat pump technology and applications. It also includes the text of the 'Wärmepumpen' magazines, a brochure on heat pump support measures, and a demonstration version of a database which includes example projects. A separate CD-ROM containing the complete database is expected to be published in the spring.

Ammonia as a refrigerant

Available from: International Institute of Refrigeration, 177 Boulevard Maiesherbes, 75017 Paris, France. Tel: +33-1-42273235. Fax: +33-1-47631798. E-mail: iifir@ibm.net. Price: USD 24. Published in 1999, 120 pages.

This work reviews the advantages and drawbacks of ammonia used as a refrigerant, and explains how to maximise the former and minimise the latter. The publication includes an number of diagrams, along with a bibliography and an index. This reviewed and expanded edition contains also a table of thermodynamic data and comparisons of HFCs.

Kostengünstige Niedrigtemperaturheizung mit Wärmepumpe (Cost efficient low-temperature heating with heat pumps)

Available from: INFEL, Lagerstrasse 1, PO Box 8021 Zurich, Switzerland. Fax: +41-1-2994140. 140 pages. German language, with summary in English.

This report reflects the findings in the second phase of a research project on low-cost low-temperature heat pumps that focused on ecological and economical comparisons, system optimisation and controls.

Gas cooling guide

Available from: Fill-It, 1500 Hubbard Dr. Batavia, IL 60510, USA. Fax: +1-630-4065995. Price: USD 475 plus shipping costs. *This guide is a CD-ROM that includes a catalogue of gas cooling equipment, a case study library and an economic screening tool. This last item includes templates for offices, hospitals, hotels, ice arenas, nursing homes, restaurants, retail stores, schools, supermarkets, theatres and refrigerated warehouses.*

INTERNET SITE

For a list of all publications and events, visit the HPC Internet Site at

<http://www.heatpumpcentre.org>



Available from the HPC

PLEASE USE THE ATTACHED RESPONSE CARD WHEN ORDERING HPC PRODUCTS

Please note that the prices will change as of 1 May 1999. See page 8.

New! The Role of Heat Pumps in a Deregulated Energy Market

Analysis Study, December 1998
Order No. HPC-AR-5. Price NLG 160 or NLG 80 in HPC member countries.

New! Heat Pump Systems for Single-Room Applications

Workshop proceedings, December 1998
Order No. HPP-AN23-1
Price NLG 120, or NLG 60 in HPC member countries and Ca, Fr and Se.

New! Heat Pump Systems for Single-Room Applications

Final report, January 1999
Order No. HPP-AN23-2
Price NLG 200, or NLG 100 for HPC member countries and Canada, Fr and Se.

Deployment Activities for Heat Pumping Technologies

Workshop Proceedings, August 1998,
Order No. HPC-WR-20
Price NLG 120 or NLG 60 in HPC member countries.

CO₂ Technologies in Heat pumps, Refrigeration and Air Conditioning Systems

Workshop proceedings, January 1998
Order No. HPC-WR-19.
Price NLG 120 or NLG 60 in HPC member countries

Compression Systems with Natural Working Fluids

Annex 22 Workshop Proceedings, January 1998. Order No. HPP-AN22-3.
Price NLG 120 or NLG 60 in member countries and Ca, Dk, Se and UK

For further publications and events, visit the HPC Internet site at <http://www.heatpumpcentre.org>

1999 International Sorption Heat Pump Conference

24-26 March 1999 / Munich, Germany
Contact: Dr Martin Hellmann, ZAE Bayern, Walther-Meissnerstrasse 6, D-85748 Garching, Germany
Fax: 49-893294-4212
E-mail: martin.hellmann@physik.tu-muenchen.de

International Congress on Refrigeration

New solutions for the cold chain
4 May 1999 / Milan, Italy
Contact: Techniche Nuove Congressi, Via C. Menotti 14 - 20119 Milano, Italy
Fax: +39-02-7570346
E-mail: congressi@tecnnet.it

World Sustainable Energy Trade Fair

Clean Energy for the 21st Century
25-27 May 1999 / Amsterdam, The Netherlands
Contact: European Media Marketing Ltd, PO Box 259, Bromley, BR1 1ZR, UK.
Tel.: +44-181-2898989
Fax: +44-181-2898484
E-mail: sustain@emml.co.uk
Internet: <http://www.emml.com>

GeoExchange Technical Conference & Expo

16-19 May 1999 / Stillwater, OK, USA
Contact: IGSHPA, 490 Cordell South, Oklahoma State University, Stillwater, OK 74078-8018, USA.
Fax: +1-405-7445283.
Internet site: <http://www.igshpa.okstate.edu>

'99 Air Conditioning & Heating Ventilation China

Environmental Friendly Refrigeration
22-25 September 1999
Contact: Chinese Association of Refrigeration
Mr Zhong Wei Qin
Bldg 11 South No. 1 Lane,
2nd Section of Sanlihe
Xi Chent Dist., Beijing 100045,
P.R. China
Fax: +86-10-68536259
E-mail: wqzhong@263.net

Events

20th International Congress of Refrigeration of the IIR

Refrigeration into the 21st century
19-24 September 1999 / Sydney, Australia
Contact: ICR99 Secretariat, 52 Rosslyn Street, West Melbourne, Vic 3003, Australia,
Tel.: +61-3-93282399
Fax.: +61-3-93284116
E-mail: icr99@airah.org.au
Internet site: <http://www.airah.org.au/icr99>

European Geothermal Conference Basel '99

28-30 September 1999 / Basel, Switzerland
Contact: OC Secretary EGC Basel '99, Bureau Inter-Prax, Dufourstrasse 87, CH-2502 Biel/Bienne, Switzerland
Fax: +41-32-3414565
E-mail: interprax@bluewin.ch

IEA HEAT PUMP PROGRAMME EVENTS

Heat Pumps - A Benefit for the Environment

6th IEA Heat Pump Centre Conference

30 May - 2 June 1999 / Berlin, Germany
Technical visits on 3 June 1999
Conference Secretariat: VWEW, Rebstocker Strasse 59, D-60326 Frankfurt, Germany
Tel.: +49-69-6304460
Fax: +49-69-6304459
E-mail: JS@vwew.f.uunet.de

Session 1: Opening plenary session
Session 2: Markets
Session 3: Technology
Session 4: Heat Pump Systems
Session 5: Applications
Session 6: Market Strategies
<http://www.vwew.de>
<http://www.heatpumpcentre.org>

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National Team Contacts

International Energy Agency



The International Energy Agency (IEA) was established in 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an International Energy Programme. A basic aim of the IEA is to foster cooperation among its participating countries, to increase energy security through energy conservation, development of alternative energy sources, new energy technology and research and development.

IEA Heat Pump Programme

Set up by the IEA in 1978, the IEA Heat Pump Programme carries out a strategy to accelerate the development and use of heat pumps, in all applications where they can reduce energy consumption for the benefit of the environment. Within the framework of the programme, participants from different countries collaborate in specific heat pump projects known as Annexes.

IEA Heat Pump Centre

A central role within the programme is played by the IEA Heat Pump Centre (HPC), itself an Annex. The HPC contributes to the general aim of the IEA Heat Pump Programme, through information exchange and promotion. In the member countries (see right), activities are coordinated by National Teams. For further information on HPC products and activities, or for general enquiries on the IEA Heat Pump Programme, contact your National Team or the address below.

The IEA Heat Pump Centre is operated by



Netherlands agency for energy and the environment



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